

PATENT SPECIFICATION

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DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Continuous Process Microwave Heating Chamber.

I, MORRIS RICHARD JEPSON, a citizen of the United States of America, of 925 Escondido Court, Alamo, California, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to apparatus for heating food products and the like by electromagnetic wave energy and more particularly to an RF or microwave chamber having access ports which may remain open during operation whereby products may be continuously passed through the chamber.

The processing of foods by exposure to RF or microwave energy is widely practiced in industrial plants and, using smaller scale equipment, in restaurants and in homes. In each case, the principal components of the heating unit are a chamber enclosure formed of electrically conducting material and an oscillator or other source of electromagnetic wave energy which is coupled to the chamber. Owing to the low loss factor of the chamber walls, very little RF energy is dissipated therein. The energy is reflected by the chamber walls which remain cool. Virtually all foods however are lossy dielectric materials from the electrical standpoint. Foods which are placed in the chamber therefore absorb the RF and are rapidly and efficiently heated.

Basic advantages of RF or microwave heating over more conventional forms are the relatively short heating time and a greater uniformity of heating within the product. Under proper conditions, the technique is more efficient than other cooking methods in that only the product itself is heated to any significant extent and virtu-

ally all the heat produced is generated directly within the product.

It has been difficult however to utilize microwave heating on a continuous process owing to the need to eliminate any leakage of electromagnetic energy from the chamber. Leaking microwave energy can cause biological effects which are injurious to nearby personnel and may cause interference in radio and television communications. Such leakage is also wasted power which increases operating costs.

RF leakage does not pose serious problems where products are treated on a batch basis inasmuch as the chamber may be completely closed during operation without difficulty. For high volume operations, however, it is much more efficient to utilize a continuous process in which products are continually fed into the chamber, transported therethrough by a suitable conveyor, and continually removed. The basic problem encountered under these conditions is that the continuous process chamber should have permanently open access ports. Such ports, in the case of chambers operating at the higher RF frequencies, are a source of considerable leakage in the absence of corrective provisions.

For systems operating below about 100 megacycles (corresponding to a wave length of ten feet) it is possible to use a conveyor which enters and leaves the chamber through permanently open tunnels which have cross-sectional dimensions that are small in comparison with the operating wave length. This does not result in leakage inasmuch as RF will not propagate through an opening which is small relative to its wave length. From the standpoint of efficient heating, however, it is desirable that higher frequencies, typically in the range of from 400 mc to 8000 mc, for example, be employed. Higher frequen-

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cies result in lower electrical field gradients in the product and produce a more uniform heating therein. At these microwave frequencies, serious leakage will occur from openings of sufficient size to admit the product unless special isolating arrangements are employed.

The present invention provides a microwave processing chamber having open access tunnels equipped with a compact, inexpensive and efficient means for preventing any significant leakage of electromagnetic energy, the chamber therefore being adaptable to high volume continuous processing of food products and the like.

Broadly, the invention may include a heating chamber having electrically conducting walls and having a microwave generator coupled thereto through a waveguide or the like. An entrance tunnel and an exit tunnel are formed at opposite ends of the chamber and a suitable continuous conveyor extends through the chamber and the access tunnels. The microwave input is aligned to avoid the injection of RF energy directly toward the tunnels. Owing to multiple reflection of the energy from the conducting walls, and to scattering, however, some of the energy will reach the region of the tunnels. The tunnels are accordingly formed in a unique manner to absorb all but an insignificant amount of such energy.

In particular, the tunnels are comprised of an outer wall of electrically conducting material and an inner wall formed of dielectric material which is spaced from the outer wall a distance of several inches, preferably a distance at least equal to one quarter wave length of the RF energy supplied in the chamber. The space between the outer and inner walls of the tunnel is made fluid tight and is filled with a lossy dielectric liquid, water being highly suitable for this purpose.

Using the described RF injection arrangement, most of the energy in the chamber undergoes multiple reflections back and forth between opposite walls of the chamber and very little is directed straight out through the tunnel openings. RF which reaches the tunnel openings behaves in a similar manner, the energy being repeatedly reflected between opposite conducting outer walls of the tunnel as it propagates relatively slowly along the axis thereof. Such energy must repeatedly pass through the water volume and it is therefore absorbed and attenuated as it moves through the tunnel. While some energy will reach the ends of the tunnels, the leakage may be reduced at any desired value by extending the length of the tunnel a sufficient distance.

Variations in the general arrangement of the tunnel may be made to reduce the residual leakage of RF without extending the tunnel an impractical distance. If the tunnels

are inclined with respect to an axis extending through the entrance and exit openings of the heating chamber, for example, then the portion of the energy which travels directly out through the openings will also be intercepted by a water volume. Alternately, the tunnels may be provided with end walls containing a water volume similar to that of the tunnel sidewalls, access to the conveyor being provided through an opening in one sidewall of the tunnel.

With another modification, the continuously operating chamber may be employed to cook food products for differing amounts of time as may be required where such a chamber is used in a restaurant for example. Specifically, the central part of the chamber may be provided with a conventional hinged door in addition to the access tunnels through which the conveyor moves. By means of the door, articles which are to be heated to a lesser extent than those which are fed into the entrance tunnel are placed within the chamber at an appropriate position on the conveyor. To avoid energy leakage, opening of the door operates an interlock which de-activates the microwave source.

In addition to stopping the emission of electromagnetic energy from an open microwave heating chamber, the invention has other highly useful results, one being that of maintaining an adequately constant load on the microwave generator under all conditions. The product which is present in the chamber under normal operating conditions constitutes the load to which the microwave generator is matched. During start-up and shut-down, however, or through operator error, there are times when there is little or no product on the conveyor. Under these conditions, this mis-match on the microwave generator could be severe enough to cause tube damage in the absence of preventive means. The access tunnel structure as hereinbefore described provides such a means inasmuch as the RF, in the absence of any product in the chamber, reflects back and forth between the chamber walls until it enters the end tunnels. The water volume of the tunnels then absorbs the energy and functions as an RF load.

It is generally necessary to continually circulate water through the tunnel walls, to avoid boiling, and by monitoring the temperature differential between the input and output water, a useful check on the operation of the heating chamber may be maintained. A variation in the temperature differential indicates either a change in conveyor loading, a change in the output power of the microwave source, or a change in the characteristics of the product undergoing processing.

Accordingly, it is an object of this inven-

tion to provide a practical, efficient and safe apparatus for heating food products and the like by exposure to electromagnetic wave energy on a continuous process basis.

5 It is an object of this invention to provide an RF or microwave heating chamber which may have permanently open access ports into which products may be continuously fed and from which products may be continually removed.

10 It is another object of the invention to provide a means for substantially reducing the leakage of electromagnetic energy through openings in processing chambers.

15 It is another object of this invention to provide a microwave processing chamber which may utilize a conveyor for the transport of products therethrough.

20 It is still another object of the invention to facilitate the use of extremely high frequency electromagnetic wave energy for the heating of foods on a continuous process basis.

25 It is a further object of the invention to provide an RF heating chamber in which a satisfactory load is coupled to the RF source irrespective of the amount of product in the chamber.

30 It is still a further object of this invention to provide a continuous process RF heating chamber having an efficient means for monitoring changes in the processing conditions.

35 It is still another object of the invention to provide an RF chamber in which products to be heated may be continuously passed through the chamber and in which products which are processed at the same time may be selectively heated for varying amounts of time.

40 The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in conjunction with the accompanying drawing, in which:

45 Figure 1 is a perspective view of a microwave heating chamber for processing products on a continuous basis and in which electrical components and the water supply means are shown schematically.

50 Figure 2 is a partial plan section view taken along line 2—2 of Figure 1 and showing internal details of one of the access tunnels of the heating chamber of Figure 1.

55 Figure 3 is a cross section view taken along line 3—3 of Figure 1 showing details of the access tunnel.

60 Figure 4 is a cross section view taken along line 4—4 of Figure 2.

65 Figure 5 is a diagrammatic view of a modified form of access tunnel for the heating chamber of Figure 1 in which the leakage of wave energy is further reduced, and

70 Figure 6 is a diagrammatic view of a

second modified form of access tunnel for further reducing the emission of microwave energy from the chamber of Figure 1.

Referring now to the drawing and more particularly to Figure 1 thereof, the heating chamber of the installation is formed by a long housing 11 which is open at the ends and which may be of rectangular cross section. At least the interior walls of the housing 11 are formed of a highly conductive material such as aluminum or copper. The central portion 12 of housing 11 is of slightly greater height than the ends 13 and 14 thereof to define the microwave injection region.

80 A microwave generator 16, which may be an oscillator, for example, is coupled to the central portion 12 of housing 11 through means such as a waveguide 17, the waveguide being arranged to inject the microwave energy in a direction normal to the long axis of the housing 11, in this instance directly downwardly from the central region of the top of the housing.

85 The product to be heated, which may be cuts of meat 18, for example, is carried through the housing 11 by a conveyor belt 19. The upper portion of the continuous belt 19 extends through housing 11, at a level which is a small distance above the floor thereof, and extends for a distance from each end thereof. The belt 19 is mounted on drums 21 and 22 at opposite ends 13 and 14 of the housing 11 with the lower section of the belt passing beneath the housing. The belt 19 is formed of a flexible electrically non-conductive and preferably non-absorbent material, any of various well known plastics or treated fabrics being suitable for this purpose.

90 To drive the belt 19, drum 21 at the entrance end of the housing 11 is turned by an adjustable speed electrical drive motor 23 which is coupled to the drum through a speed reduction mechanism 24.

95 In those cases where it may be desired to heat different units of the product 18 for differing periods of time, such as is required in the cooking of steaks in a restaurant for example, the operator's side of the housing 11 may be provided with a door assembly 26. By means of the door, products 18 may be removed from the heating chamber prior to making a complete passage through the housing 11 or alternately may be placed in the chamber at an advanced position on the belt 19.

100 Door assembly 26 may be comprised of a conductive plate 27 having a lower edge attached to housing 11 by a hinge 28 along the bottom of a rectangular opening 29 in the sidewall of the opening. A suitable handle and latch 31 is mounted on the upper margin of the door to secure the door in the closed position. To avoid energy leakage

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upon the opening of door 28, a normally open interlock switch 32 is mounted on the housing 11 in position to be closed by a portion of the door plate 27 only when the door itself is in the closed position. One of the leads 33 which supplies electrical power to the apparatus, through a control switch 34, is connected to both the microwave source 13 and belt drive motor 23 through the interlock switch 32. Opening of the door assembly 26 thus stops both the injection of RF into the housing 11 and the motion of the conveyer belt 19.

Considering now the means by which the leakage of energy from the ends of housing 11 is reduced to a negligible value, thick-walled tunnel assemblies 36 and 37 are disposed at ends 13 and 14 respectively of the housing. The conveyer belt 19 passes through each of the tunnels 36 and 37, which may be of rectangular cross-section and which in effect form a continuation of the housing 11.

Referring now to Figures 2, 3 and 4 in conjunction there is shown the internal construction of one of the tunnels 37, the other tunnel 36 being of essentially similar design. The tunnel 37 includes an outer wall 38 formed of electrically conducting material and shaped into a rectangular fluid tight enclosure of greater height and width than the adjacent end 14 of housing 11. The end of the wall 38 which is adjacent housing end 14 is turned inwardly to form a juncture therewith and the opposite end of the wall is angled inwardly in a similar manner.

Spaced inwardly from wall 38 is a rectangular inner wall 39 having a height and width corresponding to that of the end 14 of housing 11. Inner wall 39 extends through the length of the tunnel 37 and is secured to the inwardly turned ends of the outer wall 38 in a fluid tight manner. To add strength and rigidity to the inner wall 39, projections 41 formed along each corner thereof extend to the corresponding corners of the outer wall 38. To allow for the circulation of water 42 between the walls 38 and 39, openings 43 are provided along the length of each projection 41. The inner wall 39, including projections 41, is formed of a dielectric material such as plastic, glass, ceramic, or the like which is transparent to microwave energy.

Referring now to Figure 4 in conjunction with Figure 2, the containment of microwave energy within the housing 11 may be enhanced by utilizing an electrically conductive baffle 44 to limit the passageway at end 14 of the housing to the minimum area needed for passing the particular products 18 which are to be processed. The baffle 44 in this embodiment includes a rectangular plate 46 conforming to the cross-sectional configuration of the housing end 14 and secured transversely therein. A narrow horizontal

slot 47 is provided in plate 46 through which the conveyer belt 19 passes and a larger opening 48 is contiguous with the slot to provide for the passage of product 18 through the baffle. The effectiveness of the baffle is increased by providing a lip 49 around the margins of the opening 48, and beneath the belt 19, which projects backwardly into the housing 11 for a distance of several inches.

Referring now again to Figure 1, water is circulated between the inner and outer walls of the tunnels 36 and 37 from a source 51 which is connected to a fitting 52 at the base of each tunnel through a control valve 53 and branched supply conduit 54. Outlet fittings 56, which are transpierced through the outer wall 38 of each tunnel at the top thereof, connect with an outlet conduit 57 leading to a drain or a cooling and recirculating system.

To provide a means for indicating the temperature differential between the incoming and outflowing water, for monitoring the processing conditions as hereinbefore described, a first thermometer 58 is coupled to the supply conduit 54 and a second thermometer 59 is situated at output conduit 57.

In operation, the belt drive motor 23 and microwave source 16 are energized by closing switch 34. Units of the product 18 are then periodically placed on the belt 19, the product thereby being carried through the heating chamber at a uniform rate. Changes in the degree of heating of the product 18 may be made by adjusting the output power of the microwave source 16 or by varying the speed of the conveyer belt 19. If a particular unit of the product 18 is to be heated to a lesser extent than the remainder of the product undergoing processing at the same time, it may be removed through door 26 prior to making a complete passage through the housing 11 or, alternately, it may be placed at an advanced position on the belt 19 by means of the door.

The microwave energy injected into housing 11 through waveguide 17 is repeatedly reflected between the conducting walls of the housing and in this manner propagates toward the tunnels 36 and 37. Thus the energy passes repeatedly through the product 18 and a portion of the energy is absorbed thereby with each passage. The absorbed energy appears as heat within the product 18.

The energy which reaches the tunnels 36 and 37 without being absorbed by the product 18 propagates along the tunnels in a similar fashion, i.e., by reflection between opposite portions of the conducting outer walls 38 thereof. In so doing, the energy must pass repeatedly through the lossy water volume 42, as well as the product 18 in the tunnel, and is therefore almost completely

attenuated prior to reaching the open ends of the tunnels.

A typical embodiment of the invention as shown in Figure 1 has a housing 11 with a height, at central portion 12, of 11 inches and a width of 20 inches. The central portion 12 of the housing has a length of 8 feet. Tunnels 36 and 37 are 2 feet long and the thickness of the water volume 42 in the walls thereof is 4 inches. Microwave source 16 may be operated at a frequency ranging from 400 to 8000 megacycles with a power output from one to several hundred kilowatts. In a unit having the dimensions given above, and designed for industrial food processing, a typical power input is 60 kw.

Modifications may be made in the tunnel structure to reduce the escape of RF energy to a still greater extent. As shown in Figure 5 for example, the tunnel 36' may be inclined with respect to the adjacent end 14' of the heating chamber so that the small proportion of the microwave energy which travels directly out the housing chamber opening will also be intercepted by a water volume. For this purpose, the tunnel 36' should be inclined sufficiently that the upper edge 61 of the outer end of the tunnel is below the level of the floor of the housing end 14'. The angle at which the conveyor belt 19' must travel to enter and leave the heating chamber may be reduced, while satisfying the foregoing condition, by lengthening the tunnel 36' an appropriate amount. Minimizing this angle also has the beneficial effect of increasing the distance which horizontally directed microwaves must travel through water.

Referring now to Figure 6, an alternate arrangement for interposing a water volume in the path of microwave energy which travels directly along the tunnel 36'' consists of providing an endwall 62 thereon, the endwall containing a water volume similar to that heretofore described. A thin slot 63 in endwall 62 provides for the passage of the conveyor belt 19'' and a large opening 64 is provided in a sidewall of the tunnel 36'', near the end thereof, for the introduction or removal of product.

The term "conveyor" as used herein is intended to include other means for transportation than mechanical belts or the like; and in fact may include pipes, conduits, etc. whereby fluidized materials such as chemicals, powders, grains, or other materials including foodstuffs or drugs may be transported therethrough.

Although the invention has been herein discussed primarily with reference to the processing of food products, the apparatus may also be utilized for the continuous processing of other lossy dielectric materials which require heating. The invention may, for example, be employed for such purposes

as hardening thermosetting plastic products or for curing plywood.

While the invention has been disclosed with respect to a particular embodiment and certain specific modifications thereof, it will be apparent that many variations are possible within the spirit and scope of the invention and thus it is not intended to limit the invention except as defined in the following claims.

WHAT I CLAIM IS:—

1. An apparatus for heating substances by means of microwave energy, comprising a heating chamber, tunnel means communicating with said chamber and providing a passageway through which material to be heated may be passed into said chamber, means for injecting microwave energy into said chamber whereby said energy is dispersed in said chamber to a lesser extent in said passageway, a body of lossy dielectric liquid disposed within said tunnel means and exposed to radiation of microwave energy in said passageway thereby microwave energy radiated into said tunnel means from said passageway is attenuated by the liquid of said body, and means for circulating lossy liquid through said body.

2. The apparatus as set forth in claim 1, wherein said heating chamber has electrically conducting walls, said tunnel means has an electrically conductive outer wall, a dielectric inner wall disposed within at least a portion of said tunnel means and spaced from said outer wall thereof to form a fluid-tight passageway therebetween, said means for circulating the liquid circulating said liquid between said inner and outer walls of said tunnel means.

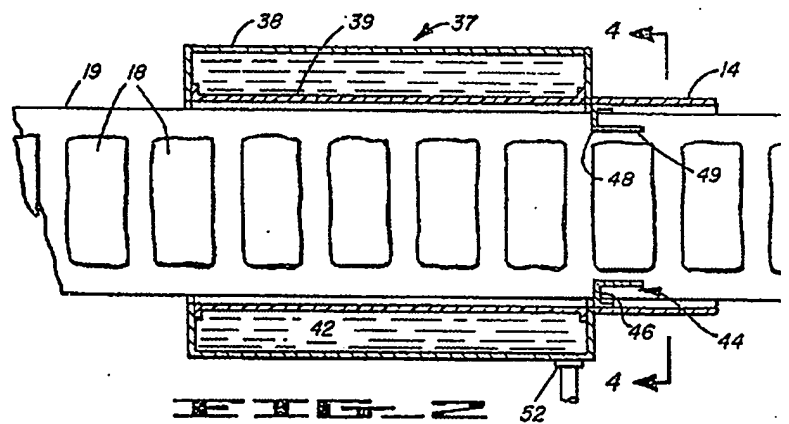
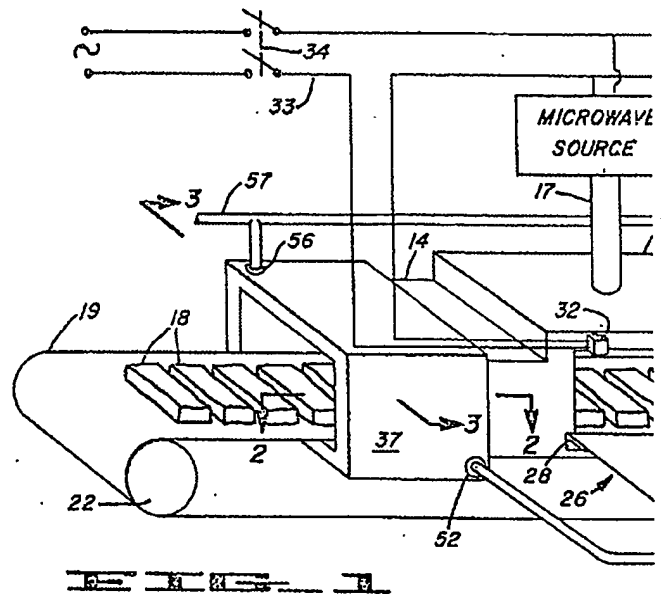
3. The apparatus as set forth in claim 1, wherein said chamber has electrically conducting walls, said tunnel means comprises a pair of tunnels transpierced through the walls of said housing at spaced apart regions thereof, said tunnels having electrically conducting walls, a fluid-tight enclosure being disposed within each of said tunnels for retaining a volume of said liquid adjacent an extensive area of the conducting walls of each thereof, said enclosures being formed of non-conductive material, and there is provided a conveyor means extending through each of said tunnels and said heating chamber for carrying said products therethrough.

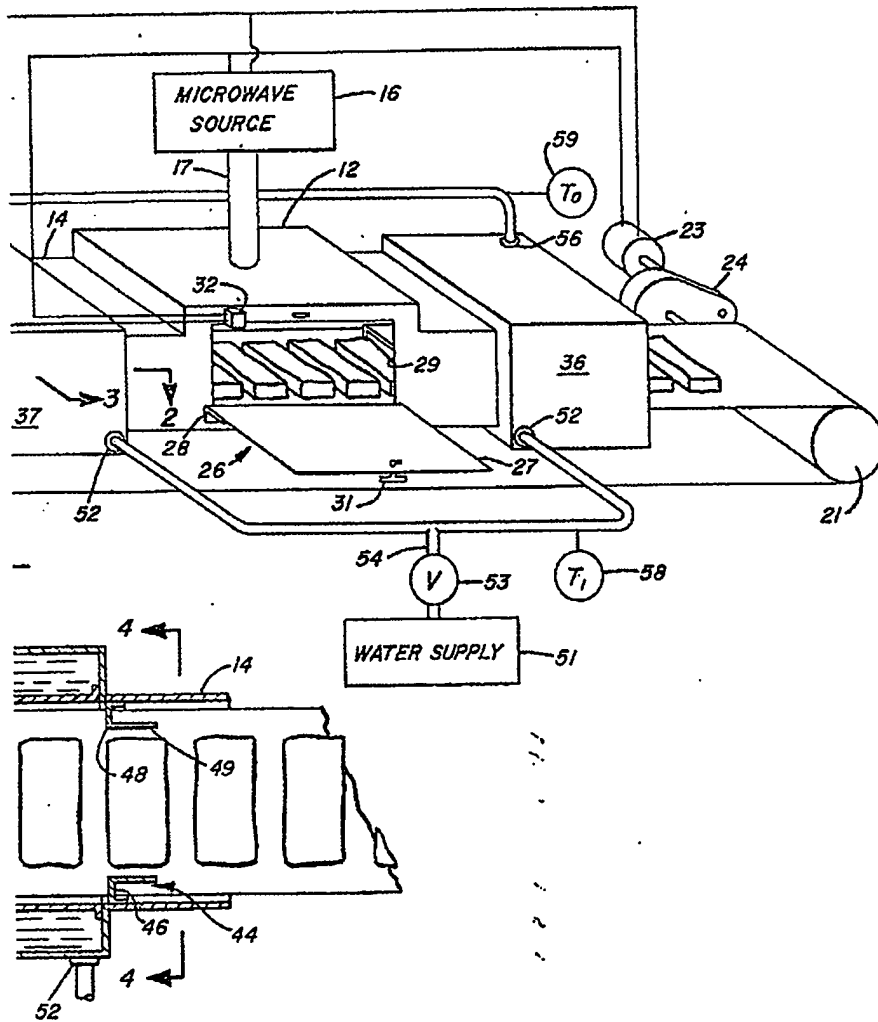
4. The apparatus as set forth in claim 1, 2 or 3, wherein said liquid is water.

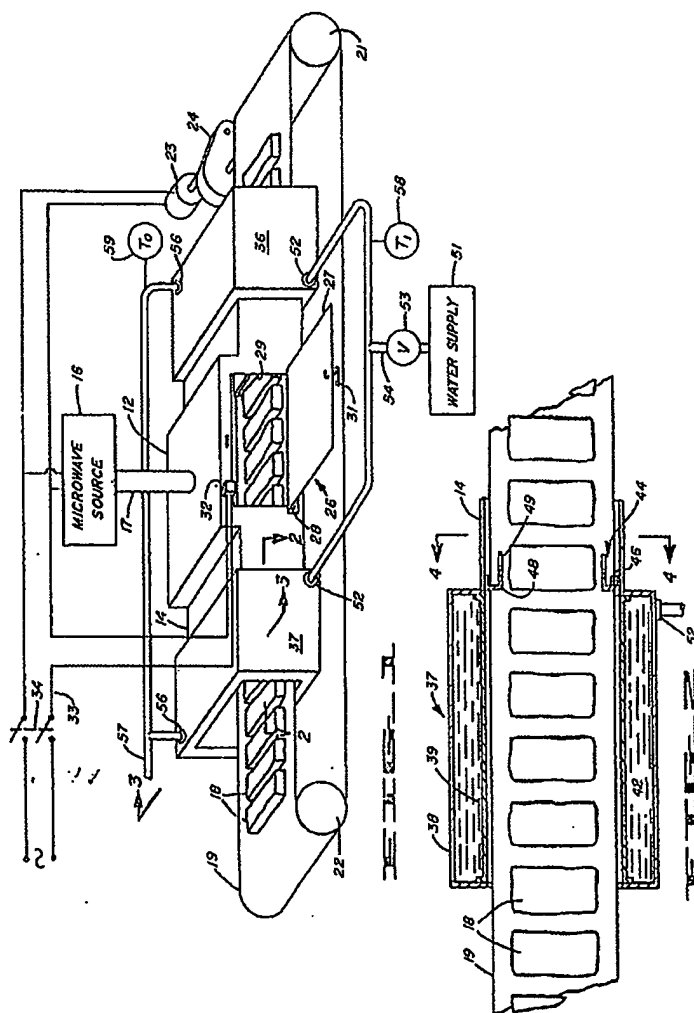
5. The apparatus as set forth in claim 3, wherein said liquid is water and there is provided a water supply conduit connected to said enclosure of each of said tunnels, said supply conduit being coupled to a source of water under pressure, a drain conduit connected to said enclosure of each of said tunnels, and a first thermometer

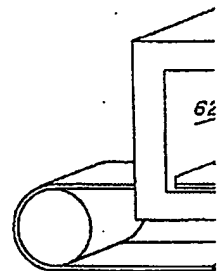
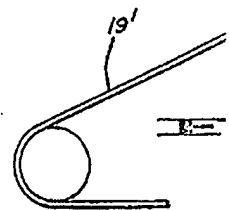
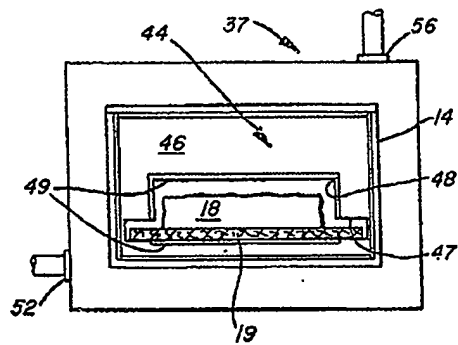
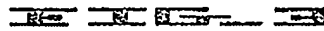
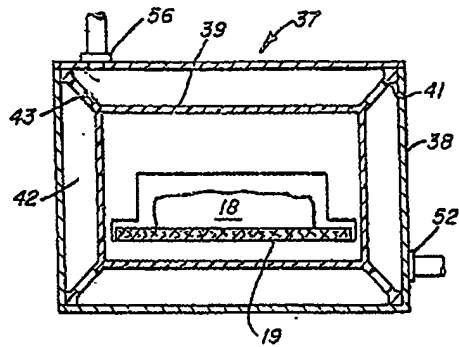
- coupled to said drain supply conduit and a second thermometer coupled to said drain conduit whereby the temperature differential between water entering and leaving at least one of said tunnels is indicated, thereby providing a means for monitoring processing conditions within said heating chamber. 20
6. The apparatus as set forth in claim 5, wherein said tunnels are inclined with respect to the centerline of the housing. 25
7. A process for treating materials with microwave energy, comprising maintaining a microwave treating zone by injecting microwave energy into a chamber while maintaining an opening in said chamber for introduction of material to be treated, said process including containing microwave energy which leaks from said chamber through said opening within a confined zone, passing material to be treated through said treating zone, and circulating lossy liquid in said confined zone and into exposure to microwave energy in said confined zone whereby said lossy liquid attenuates said microwave energy in said confined zone by absorption. 30
8. An apparatus for heating substances by means of microwave energy substantially as described and illustrated in the accompanying drawings.

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& ROLLINSON,
Chartered Patent Agents,
Agents for the Applicant.









1043290 COMPLETE SPECIFICATION

2 SHEETS

*This drawing is a reproduction of
the Original on a reduced scale*

Sheet 2

